

# **Radiation monitoring and remediation of the territories of the Russian Federation contaminated as a result of the Chernobyl accident**

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**Abstract.** Results of the monitoring of the territories in the Russian Federation contaminated after Chernobyl accident are presented for 1996-2010 years.

## **INTRODUCTION**

As a result of the accident at the Chernobyl Nuclear Power Plant on April 26, 1986, 19 territories in the Russian Federation were exposed to  $^{137}\text{Cs}$  contamination at the levels more than  $1 \text{ Ci/km}^2$  ( $37 \text{ kBq/m}^2$ ). On all the territories affected in 1986 the total land area of  $64690 \text{ km}^2$  was contaminated at such levels. Studies were undertaken in all cities, villages and settlements in which the  $^{137}\text{Cs}$  contamination levels were higher than  $1 \text{ Ci/km}^2$  ( $37 \text{ kBq/m}^2$ ), as well as with much lower levels in order to determine the extent of radiation contamination. Of all Russian regions, the Bryansk region was worst affected by the contamination following the Chernobyl accident. With this in mind, data were gathered about the contamination of the near-surface air layer and water bodies in this region.

## **MATERIALS AND METHODS.**

In accordance with the law of the RF "About social protection of citizens exposed to radiation as a result of the Chernobyl accident" put in force on 18 June 1992, the currently populated territories contaminated after the accident are divided into 3 zones depending on the contamination density.

1. The resettlement zone : the territory with the  $^{137}\text{Cs}$  concentration above  $15 \text{ Ci/km}^2$  ( $555 \text{ kBq/m}^2$ ), or  $^{90}\text{Sr}$  concentration above  $3 \text{ Ci/km}^2$  ( $111 \text{ kBq/m}^2$ ), or  $^{239,240}\text{Pu}$  above  $0,1 \text{ Ci/km}^2$  ( $3,7 \text{ kBq/m}^2$ ). On the areas of the resettlement zone where the soil contamination density was above  $40 \text{ Ci/km}^2$  ( $1480 \text{ kBq/m}^2$ ) the population was subject to compulsory evacuation
2. The zone in which residents were entitled to be resettled: the territories with the  $^{137}\text{Cs}$  concentrations in the range  $5\text{-}15 \text{ Ci/km}^2$  ( $185\text{-}555 \text{ kBq/m}^2$ ).

3. The zone with residents having social and economic privileges: the territory with the  $^{137}\text{Cs}$  contamination density within 1-5 Ci/km<sup>2</sup> (37-185 kBq/m<sup>2</sup>).

A total of 11560 population centers have been studied to obtain experimental data about the extent of contamination over the past 24 years after the accident. Gamma radiation dose rates in the population centers were measured and soil was sampled for gamma spectrometry and radiochemical analysis. The studies have shown that the  $^{90}\text{Sr}$  and  $^{239,240}\text{Pu}$  soil contamination density in all the population centers is below the levels required for establishing the resettlement zone. That is why the population centers are assigned to one of the three zones based on the locality-averaged contamination density with respect to  $^{137}\text{Cs}$ . As of 2010, 2997 population centers in 15 regions occurred on the territory with the  $^{137}\text{Cs}$  contamination density within 1-40 Ci/km<sup>2</sup>.

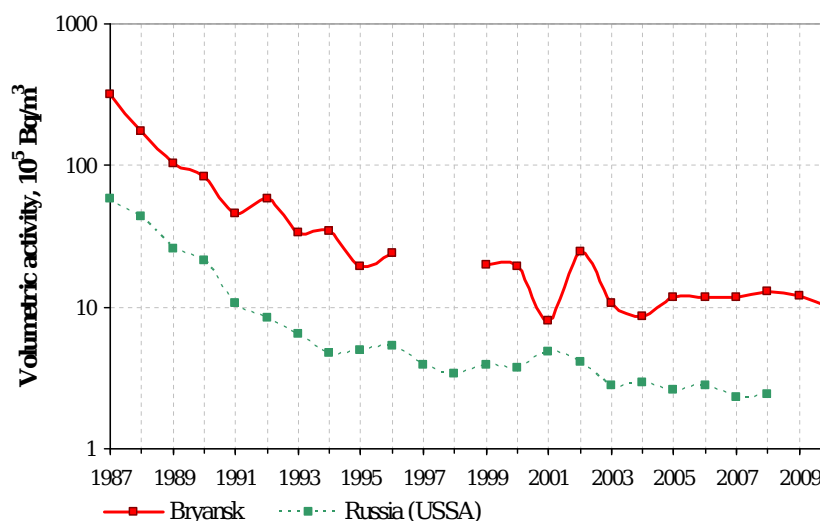
In the years to come, the number of population centers with the contamination levels in this range will be decreasing. Calculations were performed to determine the years on which the population centers will stop to belong to a specific contamination zone and be transferred to a lower category. Table 1 shows results of the calculations.

**Table 1.** Year on which the last population center of each listed area will be transferred to lower category in terms of  $^{137}\text{Cs}$  contamination

Region	1-5Ci/km <sup>2</sup>	5-15Ci/km <sup>2</sup>	15-40Ci/km <sup>2</sup>
Belgorod	2048		
Bryansk	2180	2110	2063
Volgograd	2020		
Voronezh	2044		
Kaluga	2100	2030	
Kursk	2050		
Leningrad	2044		
Lipetsk	2039		
Mordovia	2040		
Oryol	2077	2007	
Penza	2050		
Ryazan	2054		
Tambov	2007		
Tula	2109	2039	
Ulyanovsk	2011		
Total	2180	2110	2063

The calculation results presented in Table 1 indicate that there will be no population centers contaminated at the levels above 15 Ci/km<sup>2</sup> (555kBq/m<sup>2</sup>) by 2063, by 2110 the contamination levels in all population centers will be below 5 Ci/km<sup>2</sup> (185kBq/m<sup>2</sup>) and by 2180 no population center will show the contamination density above 1Ci/km<sup>2</sup> (37kBq/m<sup>2</sup>).

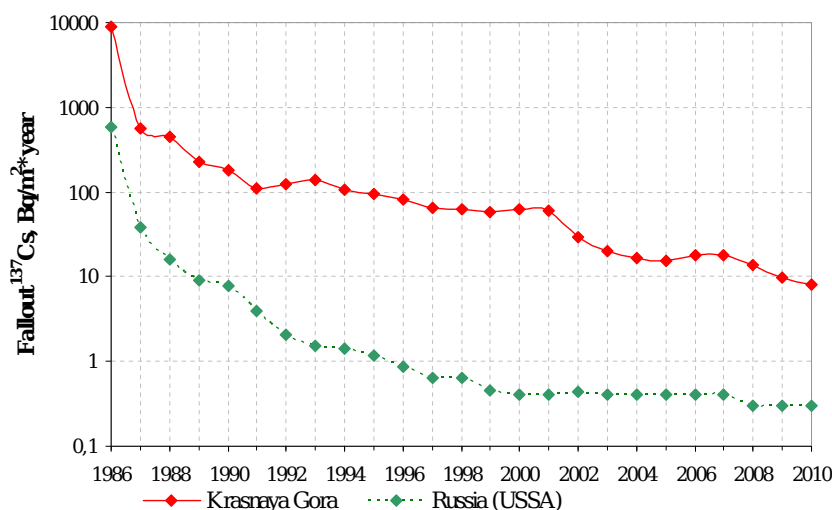
Of all Russian regions, the Bryansk region was exposed to the worst contamination following the Chernobyl accident. That is why, data were gathered about the state of contamination of the near-surface air and water bodies in this particular region. Figure 1 provides information on changes in the average annual  $^{137}\text{Cs}$  volumetric activity in the near-surface air in the city Bryansk.



**Figure 1.** Changes in the average annual  $^{137}\text{Cs}$  volumetric activity in the air in city Bryansk since the Chernobyl accident.

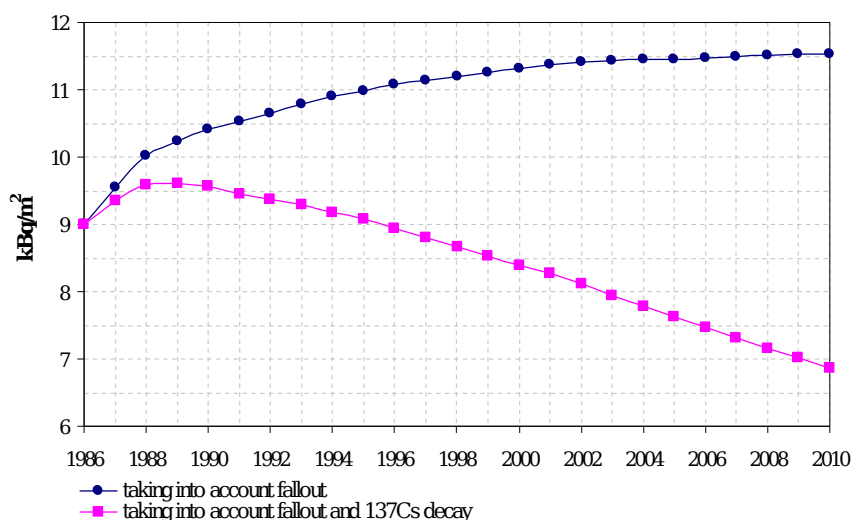
As can be seen from the figure, the volumetric activity decreased by an order of magnitude from 1987 to 1995. During the next years it changed insignificantly and was fluctuating within the range of  $1\text{--}3 \cdot 10^{-6} \text{ Bq/m}^3$ .

It may be worth noting that the forest fires in the summer 2010 did not lead to any significant change in the  $^{137}\text{Cs}$  volumetric activity in Bryansk. The measured levels are seven orders of magnitude lower than the volumetric activity permissible for the population, as established by the Radiation Safety Norms in Russia (RSN-99/2009)[2]. The levels of  $^{137}\text{Cs}$  fallout are presented for the population center of Krasnaya Gora (Figure 2) where the level of  $^{137}\text{Cs}$  contamination of soil is close to  $5 \text{ Ci/km}^2$  ( $185 \text{ kBq/m}^2$ ), however, much higher levels of soil contamination occur in the areas near the city.



**Figure 2.** Annual  $^{137}\text{Cs}$  fallout in the settlement Krasnaya Gora

Figure 2 shows that the contamination level of the fallout declined by two orders of magnitude in 5 years following 1986, there were minor changes in the level from 1991 through 2001 and subsequently it fell to six less by 2010. Figure 3 indicate as that the  $^{137}\text{Cs}$  contamination in soil due to atmospheric fallout over the past 24 years totaled  $9,8\text{ kBq/m}^2$ , 5,2 percent of which is the initial contamination.



**Figure 3.**  $^{137}\text{Cs}$  soil contamination in the settlement Krasnaya Gora

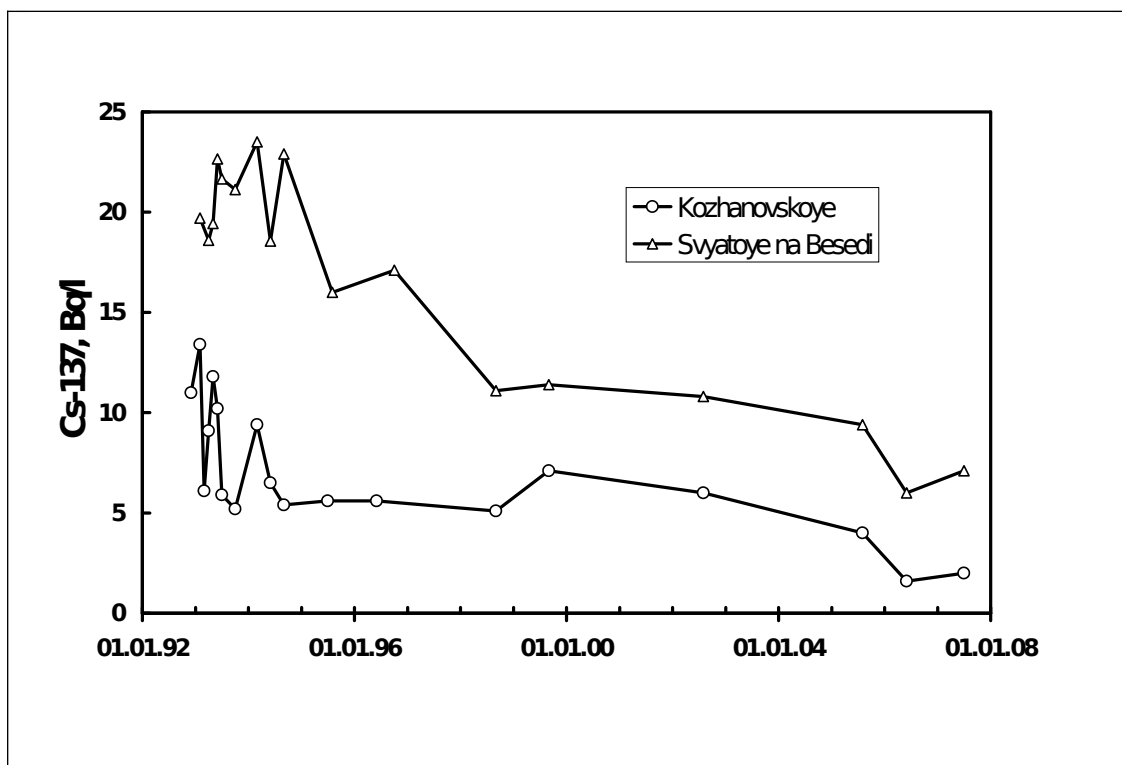
The levels of radioactive contamination in the water bodies in the Bryansk region were studied in detail [2]. Selected results of this study are presented in Table 2.

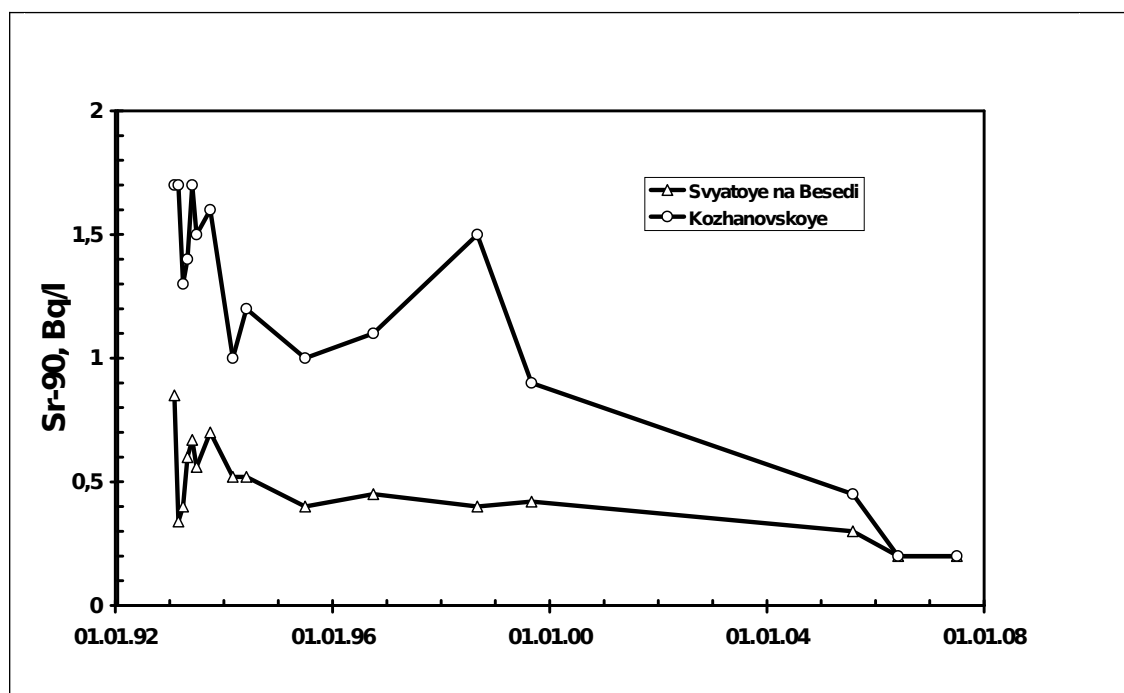
**Table 2.** Concentration of  $^{137}\text{Cs}$ ,  $^{90}\text{Sr}$  and  $^3\text{H}$  in surface water, 1998-1999 [Bq/l].

Body of Water	$^{137}\text{Cs}$	$^{90}\text{Sr}$	$^3\text{H}$
Lake Svyatoye na Besedi	11,1-11,4	0,4-0,5	1,6-2,1
Lake Kozhanovskoye	5,1-7,1	1,1-1,5	1,4-3,0
Karyer Reservoir	0,3-0,4	0,6-0,9	2,1-3,1
Ponds in rural settlements Yalovka and Nikolaevka	0,6-5,4	0,4-0,9	1,8-2,8
Rivers Iput, Besed, Snov, Korna, Vaga, Tsata.	0,01-0,02	0,02-0,09	1,9-2,7
Wells in rural settlements Nikolaevka, Zaborye.	0,05-0,4		
RSN-99/2009 [1]	11	4,9	7600

The table shows that the water levels of contamination in the rivers flowing through the contaminated areas of Bryansk region and in the wells located in the most contaminated population centers are two to three orders of magnitude

below the intervention levels established by RSN-99/2009. However, the contamination levels in water in the water reservoirs without outflow located nearby these population centers (Lake Kozhanovskoye and Lake Svyatoye na Besedi) were close to or exceeded the intervention level. With time, the contamination levels in these lakes are gradually decreasing. Fig 4 shows the change in the volumetric activity in the lake Kozhanovskoye during 1992-2007.





**Figure 4.** <sup>137</sup>Cs and <sup>90</sup>Sr volumetric activity in the water of the lakes Kozhanovskoye and Svyatoye na Besedi)

As can be seen from Figure 4 during the time period from 1992-1993 to 2006-2007 the volumetric activity of <sup>137</sup>Cs decreased to the value 2-3 Bq/l, which is 3-5 times below the intervention level established by the Russian Radiation Safety Norms [1].

## CONCLUSION

The undertaken studies of the contamination of the population centers and calculations have shown that in the beginning of 2010 the <sup>137</sup>Cs soil contamination density exceeded 1 Ci/km<sup>2</sup> (37 kBq/m<sup>2</sup>) in 1997 population centers. In the worst contaminated settlement of the Bryansk region (Zaborie), the <sup>137</sup>Cs contamination level will decrease due to radioactive decay to become below this level by 2180. The monitoring of the contamination of the environment on the territories of the Russian Federation shows that the contamination levels in the near-surface air and water bodies in 2010 are much lower the levels established by the Russian Radiation Safety Norms

## References

1. Radiation Safety Norms (RSN-99/2009), 2009, Moscow, p.100.
2. Vakulovsky S.M. et. al. 2000. Radioecological monitoring of the environment in Bryansk region in 1998-1999. In Proceedings of the International Conference on Radioactivity Associated with Nuclear Explosions and Accidents, April 24-26, 2000, Moscow, vol.2, p.19-23.